The Non-Carbon Kaolinite; Part Substituent of Cement in Concrete

ABSTRACT

Concrete extravagantly used as an anthropogenic building material, unabated in urban development. Globally the cement sector emits about 8% of CO_2 (Carbon Dioxide), generated at a ratio of 1MT of CO_2 per1MT of cement clinker sintering. Environmental concerns for its degradation through cement. To restrict cement production, natural clay materials and industrial refuges are in to substitute cement part or whole. The present-day hunt is the usage of Metakaolin (MK), a copiously accessible clay in India, as a substituent for cement. The physical, chemical, and mechanical properties of the metakaolin concrete investigated using XRF spectrometer, Scanning Electron Microscopy and universal testing machine following laboratory procedures. The efficiency of MK-concrete at different percentage mixes (0-30%) of ordinary Portland cement replacement at water-cement ratio 0.48 for all the mixes observed. The results suggested that concrete strength reduced significantly during the initial hydration period, particularly at high MK content. The application of up to 15% MK beyond 28 days curing triggers initial setting, time, rises in concrete strength, and increases durability and is also not affected by alkali-silica gel reaction, chloride and sulphate attack. Depending on the age of curing and the MK-concrete durability increases. This work shall reduce the carbon burden of present atmosphere if 15% blended MK cement concrete used

Keywords: Metakaolin, Conventional Concrete, properties of concrete, XRF study, Durability of concrete, China clay

1. INTRODUCTION

Kaolin is $Al_2O_3·2SiO_2·2H_2O$ (the hydrated Aluminum Silicate. The Metakaolin (MK) is highly reactive calcined clay, produced by charring kaolinite at 600 to 9000C. High-reactivity MK ($Al_2Si_2O_7$) is commonly available in market as china clay, used for pottery and glasses. It is one among the cementous constituents with pozzolanic properties used for high-performance concrete. As a good pozzolanic material, MK can replace cement (partly) in cement concrete (CC) and save the environmental degradation, Siddique et. al., (2009), Sposito G., (2012), and Khatib et al., (2018), Verma et al., (2021). MK optimized carefully for glazing colour, removing neutral crusts and varying particle size. The MK is extremely sensitive white powder, which is stable in look and performance. Metakaolin is of research interest as it has very much cementous property, signifying the use of Metakaolin as supplementary cementing material (SCM). MK is either the by-product or direct produce acquired by the kaolin clay calcination at a temperature between 650 and 8000 C. The CO2 emitting Portland cement is available when processed at 14500C, Glavind M., (2009).

Kaolin (a healing drug in Ayurveda) is a natural clay in (Kao-ling hill China) is safe in use as medicine during diarrhea, for sores and swelling of the mouth cavity, stops bleeding, filler for tablets, intestinal infections etc. (Attarah, 2021, NCBI -2021). The industrial application of Kaolin is paper. ceramics, ink, paint, plastics, agro-chemicals, insecticides, soaps /detergents, rubber, ink, fiberglass, catalysts, and many other trades. The green MK-concrete, the Kaolinite swell, and act as diluent, disintegrating element, binder, amorphous making, particle film coating, emulsifying, pelletizing, granulating, and suspending agent, waterproof blockade that supports construction of sewerage systems, underground tanks, waste, and nuclear storing units, Murray, (1961), Bundy (1993),. Awad et al., (2017), Boyer et al., 2021)

2. LITERATURE REVIEW

Sahin et al, 2008, Holland et. al., (2016), Dezfouli, K. K. (2021), have reported that Metakaolin as pozzolanic materials that would help to build early and long-term strength enhancing its resistance to water transportation and diffusion of harmful ions that lead to matrix degradation. Justice, et. al., (2005) mentioned that finer Metakaolin and Silica fume (8% by weight) can substitute of cement and portrays higher strengths and greater toughness, shrinkage, longevity than the standard mixes. The MK blended concrete is ecofriendly and environment sustainable material Sabir et. al., (2001), Glavind M. (2009) and Panser D. K. 2019.The Metakaolin and Fly ash (15% each by weight) have improved the concrete strength and durability Pacheco T. F. et al (2011), Li et al (2017). The Metakaolin decreases the concrete strength, and workability and High Range Water Reduction Admixtures (HRWRA) need in achieving to achieve the required slump due to deflocculating properties of MK particles Paiva. H et al (2012). The Metakaolin-Ca (OH)2-water and Fly ash-Ca(OH)2-water has the overall rate of reaction is high in early ordinary Portland cement blended Metakaolin (OPC-MK) concrete and initial stage there is a mild rate of action between Fly ash-Ca(OH)2-water as compared with Metakaolin-Ca(OH)2 and water Dojkov. I et al (2013). MK is a good pozzolanic material and can replace cement (partly) in cement concrete (CC), Siddique et. al., (2009), Sposito G., (2012) and Khatib et al., (2018). Blended cement concrete with MK can increases workability, performance (up to M70), self-compacting, quickly reduces initial setting time, and increases strength up to 10% replacement of cement Malagavelli et al., (2018). Metakaolin as small particle size as compared to OPC has (~1–2 μm) and higher surface area but larger in contrast to silica flume Keleştemur et al., (2010), Bakera et al (2019) .

3. Reasons for study:

The current technological advancement should adhere to the sustainable development goal (SDG) prescribed in Parish Agreement-2015 for safe, reliable, affordable, resilient, and sustainable environment combating climatic impact. In production of cement, there is excessive emission of CO2 gases pointed as a major challenge to achieve Sustainable Development Goal SDG in item 13. Cement shares more than 5% of the global CO2 emissions, which is deteriorating present environment, Damtoft et al., (2008).

The reason is the production of intensive high energy from calcined clinker and the removal of CO2 from limestone materials. To reduce atmospheric degradation from cement factories; an innovative natural material like MK can be thought off.

Present work envisages finding the behavioral changes of concrete when replace cement partly by metakaolin. Present search includes the enactment of cement concrete (CC) by blending with cement, metakaolin, and admixture and finding the mechanical properties such as compressive, tensile and flexural strength.

4. Materials and Methods

Metakaolin (MK) used in preparation of china clay (ceramics), obtained from the kaolinite on dehydroxylation. To reduce the anthropogenic environmental footprint, the cement industries need replacement through other cementous materials as CO2 production contributes 8% of total generation is from Cement Industries (IPCC 1997 and Gibbs et all 1999). India has produced 337.32MMT of cement during 2018-19, predicted to rise to 545MMT during 2025 (IBEF data 2022). To reduce the stress of CO2 on the biodiversity, it is essential to replace cement by some similar constituent materials. Different waste products like red mud, pumecrete, ground granulated blast furnace slags, fly ash etc. have been tried and partly successful (Nayak and Mishra, 2017, Majumdar and Mishra 2017, Das and Mishra 2020) which are industrial waste products and in addition add to environmental pollution during their disposal.

Kaolinite (alumina, (39.8 %); silica, (46.3 %); water (13.9 %) is an easily available soil as Kaolin along the east coast of India. It has cementous properties. Testing of the mechanical strength and durability of CC, the cement can have replacement with Metakaolin fine aggregates (MKF) at various proportions. Without the presence of free calcium chloride, other technological advantages were under evaluation for the substituted MK-concrete and the similar mixes of conventional cement concrete (CC) mixes.

Present study envisions judging the interactive change of CC on substitution by metakaolin replacing cement. Besides, this search includes the investigation of performance of CC by using both metakaolin and admixture with respect to mechanical strength such as compressive, tensile and flexural.

(A) Kaolin as Clay minerals India

The cement industry projected to surge 550-600 MMT/annum (MTPA) by the year 2025.To moderate the CO2 concentration on biodiversity, it is high time to substitute cement with some equal materials with similar constituent. Different waste refuges from various industries, those have stress on environment pollution are red mud, ground granulated blast furnace (GGBS), pumecrete, refinery slags, coal fly ash etc., have been tried and partly successful (Nayak et al., 2017, Majumdar et al., 2017, Das et al., 2020). Metakaolin preferred as a replacement source of SCM. Metakaolin is an ingredient to prepare china clay (ceramics) when de-hydroxylation of kaolin. The possibility of exploration of 29.35bn MT of kaolin in different pockets in India. , The state wise resources depicted in Fig.1. The figure depicts, most of the states of the country have kaolin sources. Cement factories in India also use kaolin as their raw materials. The use of MK in India in cement and ceramic industries during 2013-2014, 2014-2015 and 2015-2016 were 1.4MMT, 1.3MMT and 1.6MMT, respectively.

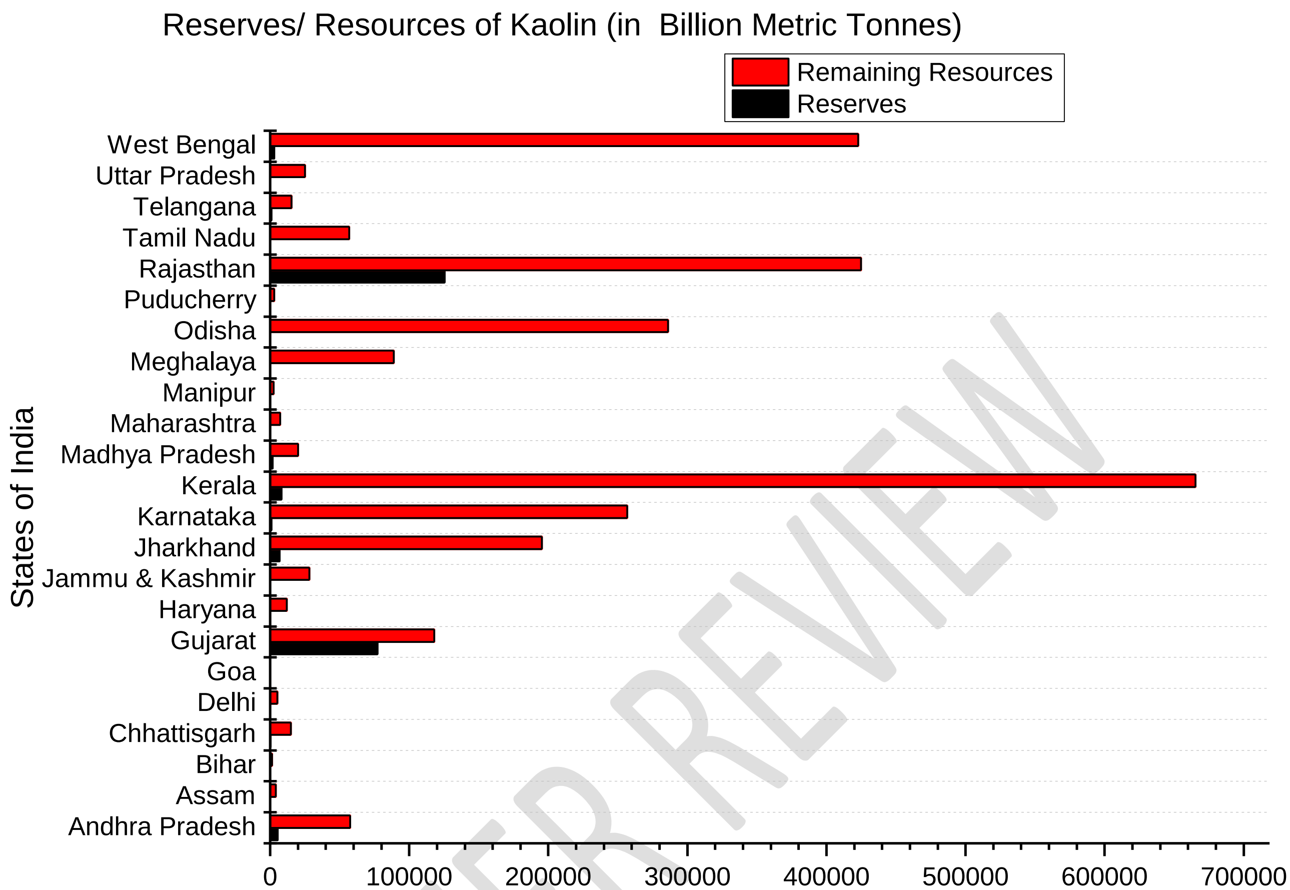

Fig 1: The state wise reserves and resources of Kaolin in India (20175); Sour: Indian Mineral book -2018 (57^{th} edition, Kaolin)

5. Chemistry behind OPC-MK concrete:

(A) Kaolin:

Kaolin (Al2Si2O5 (OH) 4 with 0-4molecules of H2O) is white soil available in the village Gaoling in Jianxi province, China. It was used in past for preparation of famous china pottery. Metakaolin, has the advantage of very fine particle size of ~ 1.0 to 2.0µm with large surface area which undergo quick pozzolanic reaction that lower the diffusion coefficient matched with OPC particle so keep MK in advantage position to replace cement. India has a potential of 29.35bnMT of Kaolin in different pockets and state wise resources is in Fig 1. Different cement factories in India are using Kaolinite as raw materials and their consumptions during 2013-14, 2014-15 and 2015-16 were 1.43mnMT, 1.28mnMT and 1.58mnMT respectively. They used not only in cement factories but also in ceramic, cosmetic, glass and many other factories. The kaolinite soil either powdered or pelleted is under heating up to 7500 C by flash calcination or rotary kiln calcination yields Metakaolin (MK), (Verga G., 2007). On heating the Kaolinite, clay gives of two water molecules to form Al2O3.2SiO2.2H2O and later the structure breaks down and forms Al2O3.2SiO2 and the process called dehydroxylation, forming 39.5% Al_2O_3 and 46.5% SiO_2 and rest water Bilijana et. al., (2010).

$$\{Si_4\}Al_4O_{10}(OH)_8, n(H_2O)\ [n = 0\ to\ 4] \rightarrow Al_2O_3.2SiO_2.2H_2O \rightarrow Al_2O_3.2SiO_2 + nH_2O$$

$$Al_2O_3(SiO_2)_2(H_2O)_2 \quad \Rightarrow \quad Al_2O(SiO_2)_2(H_2O)_4 + (0\text{-}4)H_2O$$

$$\text{(Kaolin)} \qquad 750^0C \quad \text{(Metakaolin)}$$

India has a reserve of 2941.24MMT (2018) and state wise distribution comprises of Kerala (≈ 23%), followed by Rajasthan (19%), WB (14%), Odisha (10%) and Karnataka (9%). However, the state wise exploration of Kaolin in India are Gujarat (54%); Kerala (24%), Rajasthan (16%), WB (3%) and other states 3%. The high potential natural resource can be under best utilization if replaces cement in use as per Indian mineral yearbook 2018..

6. RESEARCH SIGNIFICANCE

To find out the mechanical strength such as compressive, tensile and flexural strength of concrete by substituting Mk by cement by proportion of 10%, 15%, 20% and 30%

To study the behavioral change of concrete when used with metakaolin in replacement of cement.

To study physical properties of concrete like permeability, durability, flexibility etc.

To prepare a concrete with more advantages than the conventional concrete.

The performance of concrete by using both metakaolin and admixture studied to know the deviations in compressive, tensile and flexural strength.

7. MATERIALS USE IN EXPERIMENTAL INVESTIGATION

A CEMENT

Ultra Tech cement of 53 grades was in use in the MK-concrete design procedure. Specific gravity (Sp. Gr.) as 2.91, fineness modulus (FM) was 4.6%, found in the CUTM concrete laboratory.

B METAKAOLIN

The analytical study of chemical composition shown by use of the X-Ray Fluorescence Spectrometer (XRF) (Epsilon-1; PANALYTICAL) for both MK, and OPC. The chemical analysis exhibited that higher alumina and lower CaO was present in the metakaolin. In ordinary Portland cement (OPC), sample calcium oxide (CaO) is predominant (Fig 2). The Specific gravity of the cement and metakaolin were 2.91 and 2.8 respectively, and the fineness modulus (FM) of the cement and metakaolin were 4.6% and 5 respectively in close proximity. To test the mechanical strength and durability of concrete, the partial replacement of the cement by Metakaolin as fine aggregates (MKF) at various proportions tried. The longevity, durability, and strength properties tested in the laboratory of CUTM, Bhubaneswar.

Fig 2: The chemical composition of cement and MK as determined from XRF

Table 1. Comparison of chemical composition of Metakaolin and OPC grade 53 (Ultratech)

Chemical constituent	SiO_2 (%)	Al_2O_3 (%)	CaO (%)	Fe_2O_3 (%)	MgO (%)	K_2O (%)	SO3 (%)	LOI (%)
MK	53.7(%)	39.1(%)	0.7(%)	4.7(%)	0.41(%)	0.48(%)	0.25(%)	0.65(%)
OPC Cement	21.37 (%)	5.71 (%)	55.41 (%)	3.65 (%)	1.73 (%)	0.45 (%)	1.55 (%)	3.87 (%)

(C) SEM photomicrographs of metakaolin

Field Emission Scanning Electron Microscopy (FESEM) was in coupling with Energy Dispersive Spectrometer (EDS) analysis was addressed for morphologic study of metakaolin using Carl Zeiss, Germany (Model: Supra 55) (Fig 3). The photomicrographs obtained are in Fig.2. The sample exhibited high alumina content. The deficiency of CaO in MK is in attune at the time of partial blending with OPC in CC as follows

CaO (part of cement) + H2O → C-S-H (gel) + Ca (OH) 2

CaO (part of cement) + MK → C-S-H (gel)

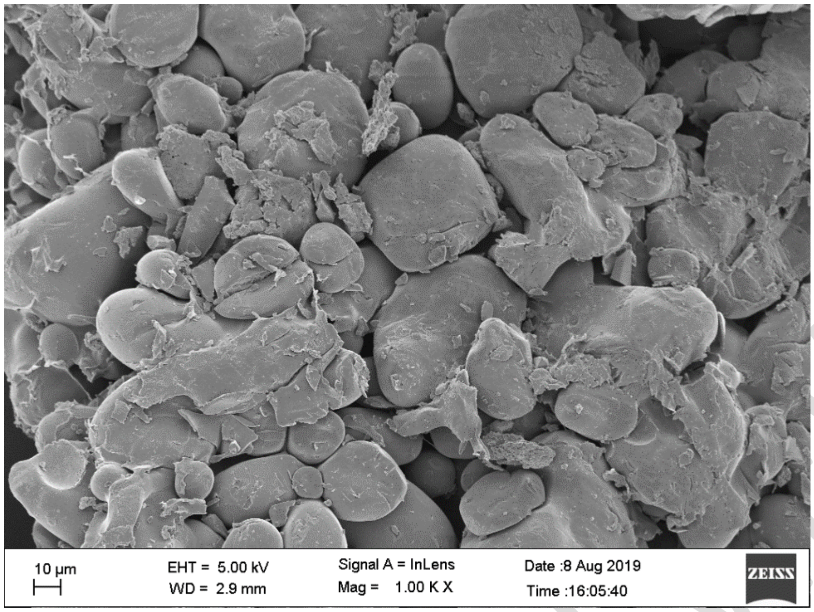

Fig. 3: The Scanning Electron Microscopy (SEM) photomicrographs of MK

(D) Advantages of MK cement concrete

1. Usage of metakaolin in concrete speeds up concrete's initial setting time.
2. Develop concrete's early age strength, allows early removal of the formwork, and thus enhances the rate of production.
3. Metakaolin absorbs calcium hydroxide thereby avoiding the alkali-silica gel reaction.
4. Metakaolin use increases resistance to sulfate attack, chemical attacks and freezing and thawing. This reduces the shrinkage and efflorescence Verma et al, (2021).

(E) Physical and chemical differences between MK and OPC

The physical properties scaling for Specific Gravity and Fineness Modulus are nearly equal. The X-Ray Fluorescence Spectrometer (XRF) (Epsilon-1; PANalytical) used to find the metal oxides present in both the OPC cement and the Metakaolin (MK) sample. After comparison, higher alumina and lower CaO percentage observed in the MK (Table -2)**.**

Table2: The difference in physical properties of cement used and the Metakaolin

Chemical Composition	Formulae	Metakaolin %	OP Cement (%)
Physical Form	Powdered Form	Powdered	Powdered
Colour		Off white	Cement colour
Specific Gravity		2.8	2.91

When MK partially substitutes cement, the deficiency of CaO, the process of adjustment of CAO in gel formation reaction is as follows

$$CaO \text{ (from cement)} + H_2O \rightarrow \text{C-S-H gel} + Ca(OH)_2$$

$$CaO \text{ (from cement)} + \text{Metakaolin (MK)} \rightarrow \text{C-S-H gel}$$

(F) Setting Time

One of the additions of water to dry concrete mix, it hydrates and changes its plastic stage to hardened stage. IS 4031 (Part 5):1988 specify that the complete cycle starts 30mnts as IST (initial setting time) after start of hydration reaction and final loss of plasticity as FST (final setting time) which takes 10hours (Table 3).

Table-3 Initial setting time (I.S.T) and final setting times (F.S.T) of Metakaolin concrete at various mix. Proportions

% of MK in mortar	Std consistency (%)	I.S.T	F.S.T
N(MK0)	35	33min	8hr55min
MK10	37	8min	8hr30min
MK15	39	5min	8hr15min
MK20	41	4min	8hr2min
MK30	43	4min	7hr50min
MK: Metakaolin; Std: Standard; I.S.T. (initial set time) F.S.T; (Final set time)			

The advantage of adding MK concrete at various grades have shown that the IST and FST is much earlier than the conventional cement concrete. Therefore, the MK concrete is best applicable for underwater concreting, closure of dams etc.

(G) Fine and Coarse Aggregates

Daya River sand was in use as fine aggregates of specific gravity of 2.64 confirming to IS 383 1970 (revised 2016) on passing through 4.75 mm sieve. Mechanically crushed black hard granite stone chips (12mm to 20mm) was in use in manufacturing in M25 Cement Concrete.

(H) Super-Plasticizer

Armix EmmeCrete PC10 (Supper arment) is a high performance super-plasticizer (carboxylic ether polymer with long lateral chains) used in this concrete mix with pH 6.0, specific gravity 1.20kg/lit. Armix EmmeCrete PC 10 have applications like achieving early strengths (compressive, flexural), eco-friendly, less permeable, reduced creep and shrinkage, highly durable and workable. The plasticizer used in high performance durable concrete for manufacture of paver blocks, Hume pipes and electric poles. The photograph of cement, Metakaolin and Armix EmmeCrete PC10 are in Fig 4 (a), 4(b) and 4(c).

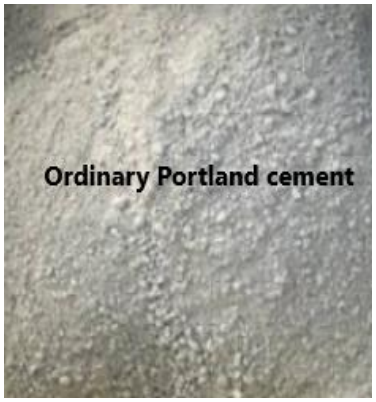

Fig 4(a). Cement Fig 4(b): Metakaolin Fig.4(c): Super Plasticizer

8. DESIGN MIX CALCULATIONS

The concrete grade M25 was prepared as per standard concrete mix (IS10262-2019 & IS456-2019). For M25 design mix, the targeted compressive strength (f'_{ck}) uses the formulae as per IS-456: 2019.

$$f'_{ck} = fck+1.65 *SD = 25 + 1.65* 4 = 31.6N/mm^2$$

Where the std. deviation (SD) = 4N/mm), for f'ck, the average (av.) target mean strength of concrete cube after 7, 14 and 28 days curing, fck = Comp. strength of the CC cube after 28 days curing. The water cement (W: C) ratio was 0.48 (dry climate). The ingredients were cement (Ultra Tech) = 400 kg / m3, Campus tap water=191.5ltr / m3, fine aggregate (sand of the Daya river) = 646.27kg / m3, Black Hard granite (HG) chips (12mm to 20mm) as coarse aggregate = 1240.32 kg\m3 of CC. The final design mix proportion by weight was 0.47:1:1.615:3.10 whereas by material weight of water, Cement, Sand and BHG chips were 191.58liters, 400kg, 646.27kg and 1240.32kg for finding the M-25 concrete. Water, Ultra Tech cement, the Daya River sand, and HG chips respectively. The CC test specimen cubes, cylinders, and beams were casted. After one day, they submerged within water supply tank for 7, 14, and 28days for different mixes.

9. EXPERIMENTAL INVESTIGATION & RESULT

The specimen cubes possessed target strength in excess of 31.6 N/mm2 for the control mixture at 7, 14 and 28 days. The details of the mixture (MK10, MK15, MK20, and MK30,) were in adaptation to examine the impact of small w/c ratio on CC containing Metakaolin on the spatial strength and durability properties. Concrete put in three layers in regular molds, and the tamping rod compacts each layer and vibrates on the table vibrator for 10 to 15 seconds for full compaction. For smooth surface, finally the top surfaces of concrete specimens were completed. Cubes (150x 150 x 150mm), cylinders (150 x 300mm), beams (100x 100 x 500mm) of standard sizes have been cast and tested for a water submerged period of 28 days and tests for comp. strength, (STS) split tensile strength & density are tabulated in Tables -4.

Table-4: Mix Proportions of various weight percentage of MK in cement concrete grade

	% of MK with various % of admixture (of binder)				
	0%CC	CC+10%MK	CC +15%MK	CC + 20%K	CC +30%MK
	MIX DESIGN				
Ingredients	MIX-M-0	MIX-M-1	MIX-M-2	MIX-M-3	MIX-M-4
Cement	400 (kg/m^3)	360(kg/m^3)	340(kg/m^3)	320(kg/m^3	280 Kg/m^3
Metakaolin (MK)	0 (kg/m^3)	40(kg/m^3)	60(kg/m^3)	80(kg/m^3)	120(kg/m^3)
Fine Aggregates (FA)	646(kg/m^3)	646(kg/m^3)	646(kg/m^3)	646(kg/m^3)	646(kg/m^3)
Coarse Aggt (<20mm)	1240(kg/m^3)	1240(kg/m^3)	1240(kg/m^3)	1240(kg/m^3)	1240(kg/m^3)
Super plasticizer	0 %	1.5%	1.75%	2.0%	2.25%
Slump in mm	78 mm	85 mm	87 mm	91 mm	96 mm
Water in liters	191 liters	191 liters	191 liters	191 liters	191 liters

Compressive strength

The compressive strength (CS) of specimen cubes augmented with adding MK in the blend initially. The max. CS achieved when 15% MK (MIX-M-2) was existent in the CC mixture (Fig 5). The results specify that the CS of the specimen cube improved with the rise in the weight percentage of MK in the blended CC up to 15% and later lessened with additional MK. Thus, the CS of the specimen cube was different which have CS between 19.25 to 22.10 N/mm2. The reasons for achieving the maximum CS can have explanation that when OPC partly replaced MK, the ultimate hydration reaction of the green concrete reached. The increase in percentage of MK weaken the Vander wall forces and hinders the hydration reaction (in Fig 5).

Table 5. Compressive strength results of cube (UTM results)

Mix Proportions	**Compressive strength of cube after curing (N/mm^2)**		**% increase/decrease in strength**
	7 days	28 days	
MIX-M0	19.28 N/mm2	30.97 N/mm2	
MIX-M1	20.97 N/mm2	34.18 N/mm2	10.36%
MIX-M2	21.62 N/mm2	35.25 N/mm2	13.82%
MIX-M3	22.18 N/mm2	36.18 N/mm2	23.28%
MIX-M4	19.95 N/mm2	33.18 N/mm2	07.14%

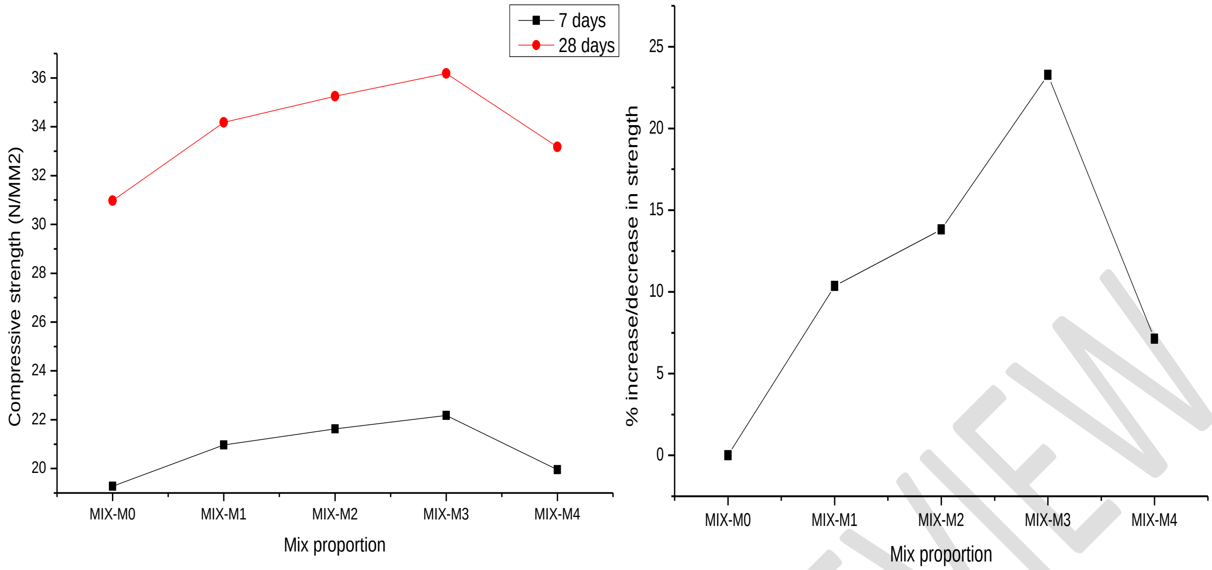

Fig 5(a) compressive *strength* of MK-conc. cube; Fig 5(b); % of increase/decrease in strength

Split tensile strength

The split tensile strength shown by the specimen (cylinder) at the beginning was in rising trend with the adding MK in the CC mixture up to 15% weight of the mix. Later that lessened with the additional blending with MK in the combination.

Table 6. The Split tensile strength of cylinder specimen as per results from UTM

Mix Sizes	Spilt tensile strength of cylinder after curing (N/mm^2)		% increase/decrease in strength
	7 days	28 days	
MIX-M-0	2.12(N/mm2)	3.22(N/mm2)	0.00%
MIX-M-1	2.28(N/mm2)	3.45(N/mm2)	7.1%
MIX-M-2	2.29(N/mm2)	3.68(N/mm2)	14.3%
MIX-M-3	2.36(N/mm2)	3.88(N/mm2)	20.5%
MIX-M-4	2.15(N/mm2)	3.35(N/mm2)	4.0%

The maximum CS achieved at 15% MK blending (MIX-M2). The results are covenant with the investigations piloted by Ayobami et al., 2019. Dinakar et al., 2013 opined that the split tensile strength of MK is flexible depending on the rise in the CS of the mixture.

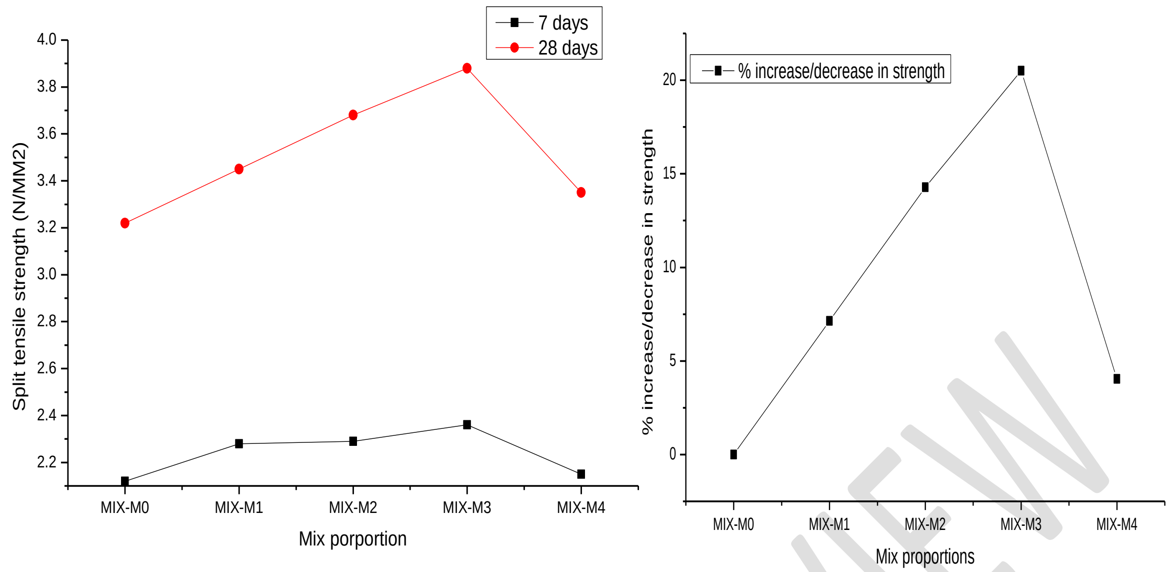

Fig 6(a). Spilt tensile strength of cylinder; Fig 6(b). Percentage increase/decrease of spilt tensile strength

Flexural strength

At the beginning, the flexural strength (FS) of the MK blended CC enhanced when partly substituted (until 15% MK addition) (Table 8). The Pozzolanic and filler action properties of the cementitious materials does so. The rise of FS properties upshots a faster hydration reaction between Ca (OH) 2 and the MK in presence of water. It proclaims that the existence of alumina in MK enhances the cementitious characteristics by C-S-H gel formation, that converts into calcium aluminates hydrates and alumina silicate hydrates (Lal and Bishnoi, 2015). After attainment of the optimal mixing percentage, the mechanical strength properties depreciate slowly as the extent of Ca (OH) 2 reduced for cementitious reactions [Table 7, Fig 7 (a) and Fig (b)].

Table 7. Flexural strength of beam (UTM results) of various mix MK concrete

Mix Proportions	Flexural Strength of specimen beam after curing (N/mm^2)		% increase/decrease in flexural strength
	7 days	28 days	
MIX-M-0	2.45(N/mm2)	3.37(N/mm2)	0.0%
MIX-M-1	2.78(N/mm2)	3.67(N/mm2)	8.9%
MIX-M-2	3.32(N/mm2)	3.74(N/mm2)	11.0%
MIX-M-3	3.16(N/mm2)	3.86(N/mm2)	14.5%
MIX-M-4	2.57(N/mm2)	3.52(N/mm2)	4.5%

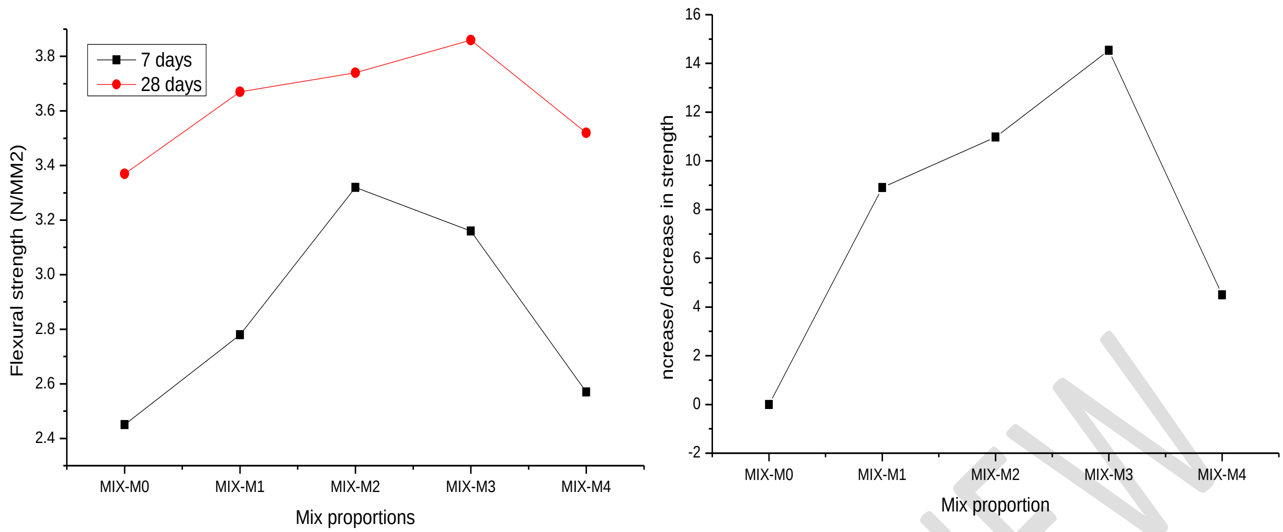

Fig 7(a). Flexural strength of beam; Fig 7(b) Percentage increase/decrease of flexural strength

Non-destructive Rebound Hammer test

Before conducting destructive tests in universal testing machine (UTM), machine a non-destructive test conducted by rebound hammer. The results obtained presented in Table 8. The non-destructive test outcome exhibit that the MK-concrete satisfies the required compressive strength as per the design mix.

Table 8: Results of the rebound hammer test conducted before conducting by UTM

#	Type of MK concrete	Test results of rebound hammer (28days curing) in N/mm^2
1	MIX-M-0	29.90 N/mm2
2	MIX-M-1	33.10 N/mm2
3	MIX-M-2	35.20 N/mm2
4	MIX-M-3	36.10 N/mm2
5	MIX-M-4	33.10 N/mm2

10. <u>Discussion:</u>

Metakaolin blended with cement to manufacture OPC-MK concrete support to recommend sustainability and environment friendly structural pursuits retaining the original strength of CC. The addition of the superplasticizer as admixture add in improving workability. The admixtures decreases CO2 releases on partial substitute of cement in CC. Present work manufacturing the superplasticizer as admixtures and metakaolin is produce of eco-friendly concrete. As India is rich in kaolinite, can easily use metakaolin as a replacement of cement in CC, which is the advancement in gaining in the sustainable development goal -13 in building sector. It is advantageous to replace metakaolin in high grade concrete and have successful performances like improved, strength, durability, quick in setting, safe from chloride attack, and sulphonation. Blended MK concrete is durable and reduce environmental pollution in coming days Wang et al., 2021, Chen et al, 2021

On replacing cement by metakaolin in concrete uses can enhance the strength properties, like compressive strength by (+23.3%), and split Tensile strength by (+20.5%), and in flexural strength as (14.5%). The blended concrete can modify the concrete characteristics, lowers cost, reduce cement consumption, enhance durability and a novice way to waste disposal. MK concrete has lower cost, as the kaolin is plenty in availability in India can be the best choice for replacement.

The mechanical strength obtained from the various laboratory works on metakaolin-blended cement concrete (CC), is compatible with the strength results obtained from various proportions with conventional CC. The compressive strength of OPC-MK concrete upsurges until 15 % cement substituted by MK. Further addition of metakaolin reduces the compressive strength as observed. Therefore, the optimal use of additional percentage of MK with OPC cement in concrete taken as 15% in specimen cubes. The inference is addition of MK reduces the workability compared to conventional parallel grade of CC. To ameliorate the problem it is essential to add super plasticizers in appropriate doses.

11. CONCLUSION

The strength of meta-kaolin-concrete with at 15% replacement of cement gives best result among all trial percentages of substitute. The meta-kaolin, (blending at 15%), the compressive strength increases by (+23.3%), and split Tensile strength by (+20.5%), and in flexural strength as (14.5%) at the age of 28 days of curing period. The following conclusions inferred from the investigation based on the impact in concrete of partial substitution of cement with Metakaolin;

Kaolin can by a suitable natural replaceable substitute for traditional concrete after calcination to metakaolin and production of Mk-Concrete.MK-concrete significantly increases the comp. and flexural strength as opposed to traditional concrete. As per literature, they are durable with quick setting properties without affected by chloride, sulphate. Workability of CC decreases as percentage of blending increases beyond 15% by Metakaolin in cement concrete. The admixture quantity needs snowballing gradually with increase in percentage of Metakaolin. The optimized strength increases with increase in Metakaolin content up to 15% replacement of cement. Controlled use of MK in cement concrete can reduce the burden of CO2 loading the Indian upper atmosphere.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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